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Assessment of Heavy Metals in Soil Impacted by Effluent Discharge from a Pharmaceutical Company

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ABSTRACT

The level of heavy metals, namely: copper (Cu), zinc (Zn), iron (Fe), lead (Pb), chromium (Cr), and nickel (Ni), in soil impacted by effluent discharge from a pharmaceutical company were assessed. This was done with the view of determining the level of pollution of the soil. Soil samples were collected at distances 0m (Discharge point I), 4.55m (Discharge point II), and 9.1 m (Discharge point III) away from the effluent discharge outlet. The soil samples were analysed using Atomic Absorption Spectrometry (AAS) to determine the concentration of the heavy metals of interest. Results showed that the concentration of lead, zinc, and iron were significantly increased at both 0 m and 9.1m points, while their concentration at the 4.55 m point was non significantly increased. The concentration of copper and chromium were significantly increased at all sampling points, while that of nickel was significantly increased only at the 0m point. Furthermore, the pollution indices at the 0m, 4.55m, and 9.1m points, were estimated as 2.3, 1.5 and 1.7, respectively, indicating that the soil could be polluted by heavy metals from the pharmaceutical effluent. This could impact negatively, microorganisms in the soil, plants grown on the soil, and even humans who feed on crops produced on the soil.

***Key words**: concentration, heavy, metals, soil, effluent, pharmaceutical, pollution*

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INTRODUCTION

The improper management of large amount of waste generated by various industrial activities, is a major source of concern in developing countries. The unsafe disposal of these industrial wastes results in the pollution of the ambient environment. Levels of pollution resulting from the unsafe disposal of these waste varies from industry to industry, depending on the type of process and the size of industry [1]. Inadequate treatment of effluent from industrial sources impacts negatively on human live due to the presence of recalcitrant substances.

Effluents from chemical and pharmaceutical industries are known to have high amounts of organic and inorganic pollutants [2], as well as heavy metals [3, 4]. Untreated or allegedly treated industrial effluents have been reported to contain variable amounts of heavy metals such as arsenic, lead, nickel, cadmium, copper, mercury, zinc and chromium [5, 6]. The effect of heavy metals pollution on the environment is the alteration of the physical and chemical properties of both water bodies and surrounding soil, as well as the general morphology of the soil [7]. These alterations are generally harmful to both the biotic and abiotic components of the ecosystem [8, 9].

The absorption, translocation and accumulation of heavy metals such as mercury, lead, chromium and cadmium by plants have been known to reduce both the qualitative and quantitative productivity of plant species, as well as constitute serious health concerns to other forms of life through the food chain [8]. Heavy metals enter aquatic environment and are absorbed unto particulate matter or form free metal

ions or soluble complexes that are available for uptake by other lifeforms [6]. The toxic effects of heavy metals to humans and other lifeforms are well studied and documented [10, 11, 12, 13, 14, 15].
In this study, the concentration of some heavy metals (Cu, Zn, Fe, Pb, Cr, Ni) present in soil polluted by effluent discharge from a pharmaceutical company located at Ogbomoso, Oyo state, South-west Nigeria, were determined. Furthermore, the level of contamination was assessed using Pollution load index, (PLI), a scheme proposed by Tomlinson and collaborators in 1980 [16]. This scheme has been used widely to determine the level of heavy metal contamination in sediments.

MATERIAL AND METHODS

Soil samples were collected at three different points from the effluent outlet of a pharmaceutical company located at Ogbomoso, Oyo state, Nigeria. The pharmaceutical company had been in operation for 10 years at the time this study was undertaken. The three sample collection points herein referred to as: Discharge point I, Discharge point II, and Discharge point III, were at distances 0 m, 4.55 m, and 9.1 m, respectively, from the effluent outlet. The control soil samples were collected, 50m away from the effluent outlet, and had no industries or commercial activities around it. At each collection point, including the control, three soil samples: the surface soil (0 m deep), top soil (10 cm deep), and sub soil (20 cm deep), were collected. The samples were air dried at room temperature for three days to reduce the water content. These were then used to determine the concentration of heavy metals in the soil samples.
The concentration of heavy metals was determined using the method described by the American Public Health Association (APHA)[17]. This involves acid digestion of the soil samples using HNO_3 and HCl in the ratio 1:3 (v/v) added to the soil sample and heated to dryness. This was followed by filtration and addition of distilled water to provide enough solution for analysis.
Metal concentrations were determined with the aid of atomic absorption spectrophotometer (AAS). The AAS was calibrated using standard solutions (solutions of known concentration) for each of the metals analysed. The digested samples were introduced to the Perkin Elmer Analyst 300 Atomic Absorption Spectrophotometer (AAS) to determine the concentrations of the respective metals of interest. The mean value for the three samples at each collection point was calculated, and used to assess the level of contamination.
The pollution load index(PLI) at a given sampling point was calculated as:

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n} \qquad 1$$

Where, n is the number of metals investigated, and CF_i is the contamination factor for the i[th] metal.
Contamination factor, CF_i, for each metal were calculated as:

$$CF_i = \frac{C_i}{C_{ib}} \qquad 2$$

Where C_i is the concentration of the i[th] metal and C_{ib} is the concentration of the i[th] metal in the background (concentration in control samples were used as backgroundconcentration).
In this scheme [16], a $PLI < 1$ implies no contamination, while a $PLI > 1$ implies contamination.
Statistical analysis was carried out using SPSS software. One-way ANOVA was used to compare the concentration of the heavy metals at the sampling points, and control.

RESULTS AND DISCUSSION

Figures 1 to 6 shows the mean concentrations at each sampling point for each of the elements of interest, namely: lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), and nickel (Ni), respectively. On each histogram, bars with different letters at the top are statistically significant ($p<0.05$), while bars with the same letter at the top are not statistically significant($p>0.05$)

Lead concentration

Figure 1 shows a significant increase ($p<0.05$) in the soil lead concentration at discharge points I and III when compared to the control. Discharge point II, however, shows a non-significant increase in the lead concentration compared to the control.
A significant increase in lead concentration at Discharge points I and III indicates the presence of lead in the effluent. This is in agreement with what has been reported in literature, that organic wastes contain some amount of lead [18]. Excess lead in the soil could be washed into ground water, leading to lead toxicity to the end users. Exposure to low levels of lead has been linked to learning disabilities, impaired neurological development and reduced metabolic activity in the body, whereas, high level lead exposure can lead to acute lead poisoning, which may result in kidney damage, coma, convulsions and even death [19].

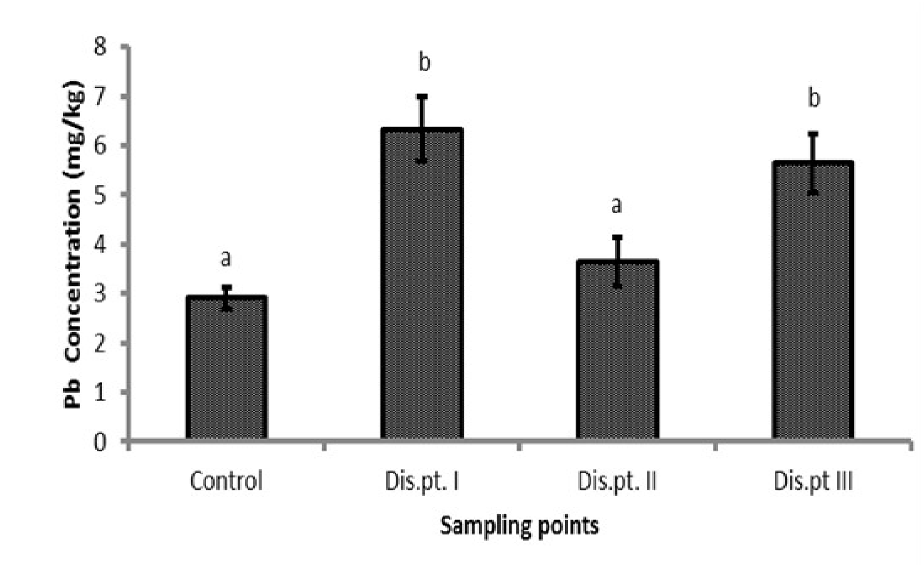

Figure 1: Concentration of lead at the sampling points

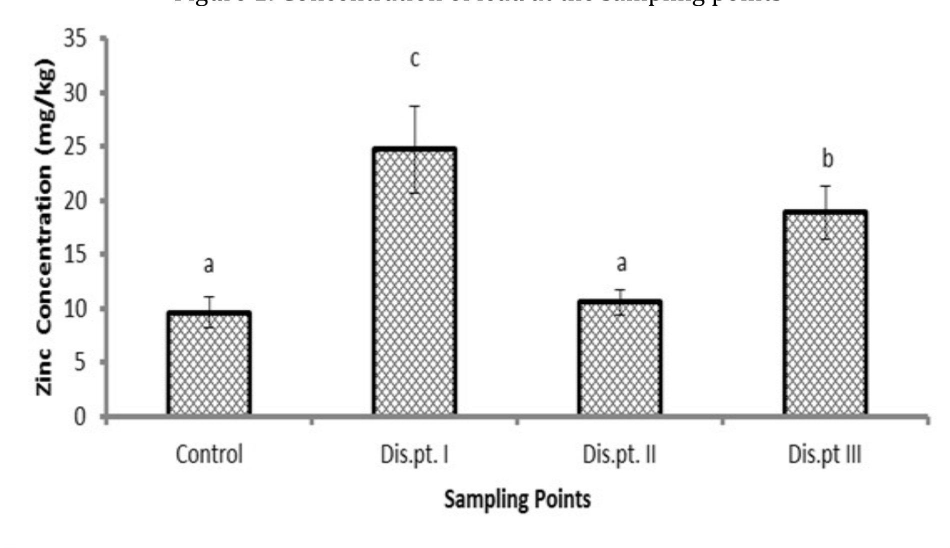

Figure 2: Concentration of zinc at the sampling points

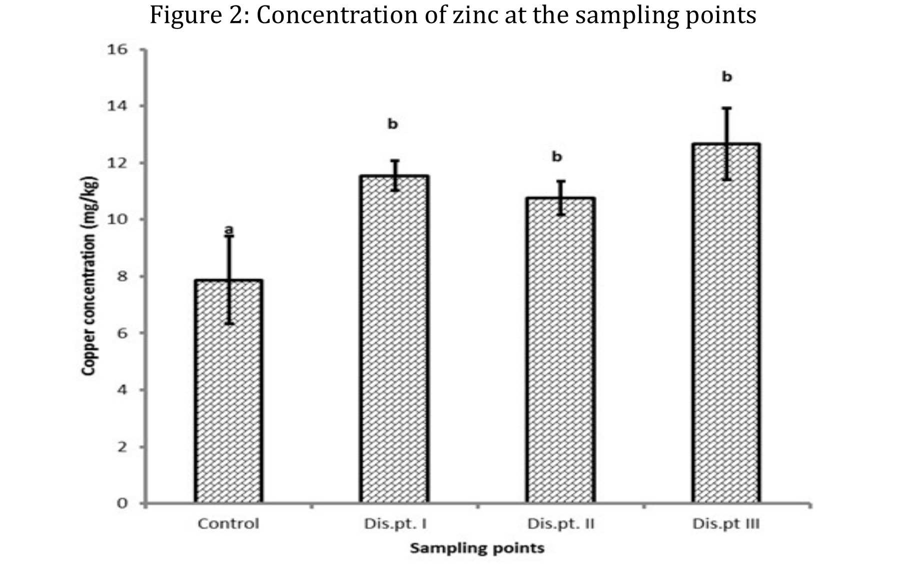

Figure 3: Concentration of copper at the sampling points

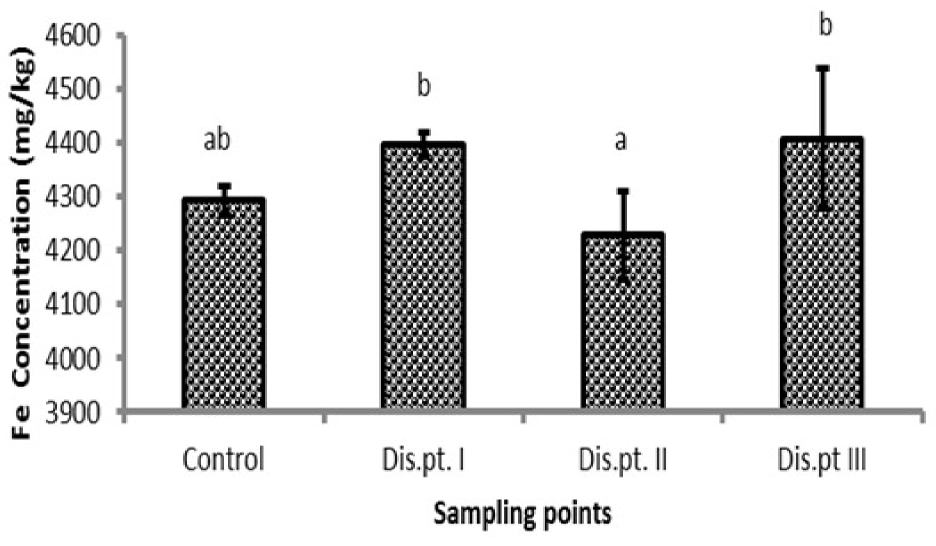

Figure 4: Concentration of iron at the sampling points

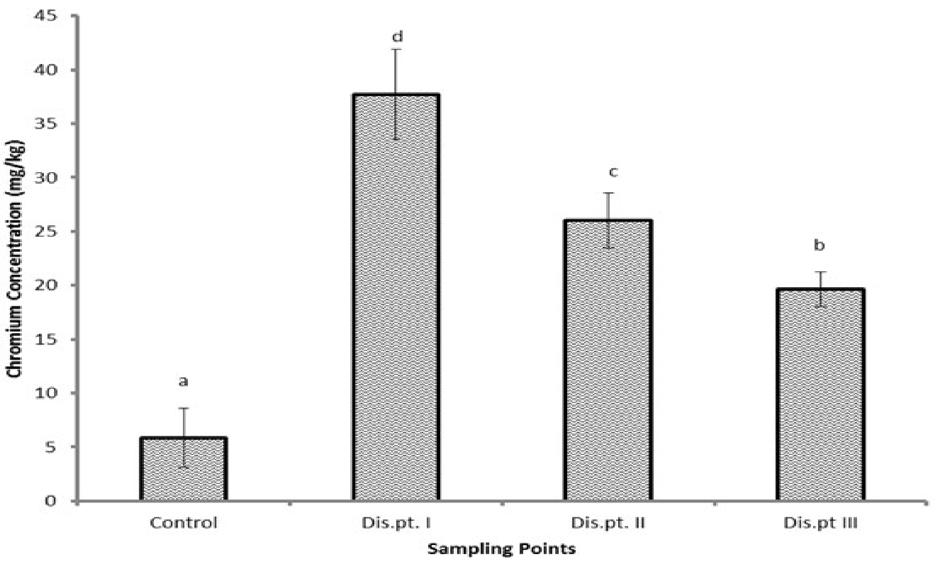

Figure 5: Concentration of chromium at the sampling points

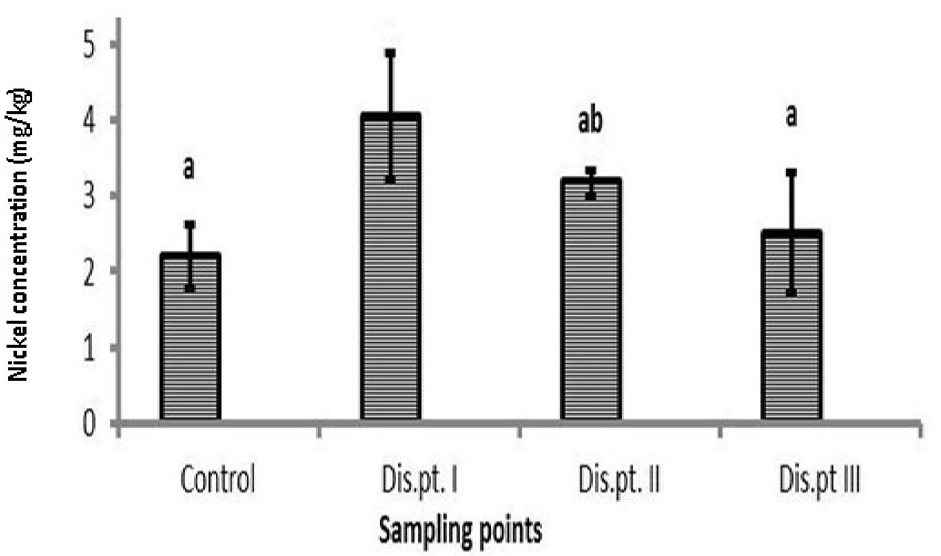

Figure 6: Concentration of nickel at the sampling points

Zinc concentration

The zinc concentration (Figure 2) in soil samples from discharge point I and III shows a significant increase ($p<0.05$) when compared to control sample. However, no significant difference in soil zinc concentration from discharge point II compared to the control.

Increase in zinc concentration at discharge points I and III suggest the presence of high amount of zinc in the effluent. Zinc in the soil can pollute ground water by increasing the acidity of the water. When zinc accumulate in soil, plants often have a zinc uptake that their systems cannot handle [20]. Furthermore, zinc can influence the activity of microorganisms and earthworms, thus retarding the breakdown of organic matter [20]. Moreover, in zinc-copper imbalance, plant roots appear to absorb zinc and copper by the same mechanism. This can cause interference in the uptake of one when the other is in excess in the root zone [20].

Copper concentration

Copper concentration compared to control, Figure [3] shows a significant increase ($p<0.05$) in the concentration of copper in soil samples from all sampling points (Discharge points I, II and III), with Discharge point III having the highest concentration.

A significant increase in copper concentration suggest the presence of copper in the effluent. The copper concentrations in these soil samples awee below the maximum permissible limits of 73mg/kg set by World Health Organization (WHO). Although the effluent may seem safe from copper toxicity [21], copper tends to accumulate more heavily in the roots of vegetation, thereby leading to copper toxicity [22].

Iron concentration

There was an increase in iron concentration at Discharge points I and III compared to the control (Figure 4), however, this increase was observed to be non-significant ($p>0.05$). On the other hand, Discharge point II shows a non-significant decrease in soil iron concentration.

An increase in iron concentration observed at Discharge points I and III points to the presence of iron in the discharged effluent. Although there was no significant difference in iron concentration at all the Discharge points compared to the control, these values, including the control, are above the FEPA recommended threshold value (400 mg/kg) [23]. An excessive uptake of Fe^{2+} by the roots and its translocation into the leaves where an elevated production of toxic oxygen radicals can damage cell structural components and impair physiological processes [24].

Chromium concentration

When compared with the control, there is a significant increase ($p<0.05$) in chromium concentration in soil samples from all sampling points, with discharge point I having the highest concentration (Figure 5).

The significant increase of chromium concentration in soil samples at all the sampling points in indicative of the presence of chromium in the effluent, which is in agreement with the findings of Vinod and Chopra [18]. The decrease in chromium concentration with increase in distance may be due to leaching into underground water. Smith and co-researchers [25] reported that chromium can be transported by surface runoff to surface waters in its soluble or precipitated form. Industrial applications most commonly use chromium in the hexavalent chromium [Cr(VI)] form, which is very mobile in groundwater and it is acutely toxic [26, 27]. Chromium is associated with allergic dermatitis in humans [28]. Direct contact with contaminated soil may also result in ocular irritation [29]. Excess concentrations of chromium, according to Orhue*et al*.[30], also decreases chlorophyll concentration by inhibiting electron transports.

Nickel concentration

Figure [6], shows that there is a significant increase ($p<0.05$) in soil nickel concentration at discharge point I when compared to the control, while discharge points II and III showed a non-significant increase in nickel concentration compared to the control.

This suggest that nickel is present in the effluent. The decrease in nickel concentration with increasing distance from the effluent outlet shows that there is leaching of nickel from the effluent into the ground. In acidic soils like effluent contaminated soil, nickel becomes quite mobile and often leaches down to the adjacent groundwater where the growth of microorganisms could be negatively impacted [31]. The toxic effects of nickel stems from its ability to sequester other metal ions in enzymes, proteins or bind to cellular compounds [32].

Table 1 shows the contamination factors for each metal, computed using Equation 1, while Table 2 is a presentation of the Pollution indices at each sampling point. The pollution indices were all found to be greater than 1.0(Table 2), indicating that the soil could be polluted with heavy metals present in the effluent discharge from the pharmaceutical company.

Table 1: Computed contamination factors for each metal at the sampling points

	Lead	Zinc	Copper	Iron	Chromium	Nickel
Discharge point 1	2.2	2.6	1.5	1.0	9.9	1.8
Discharge point 2	1.2	1.1	1.4	1.0	4.3	1.4
Discharge point 3	1.9	2.0	1.6	1.0	3.4	1.1

Table 2: Pollution index at each sampling point

	Pollution index
Discharge point 1	2.3
Discharge point 2	1.5
Discharge point 3	1.7

CONCLUSION

This study has shown the presence of heavy metals such as lead, zinc, copper, iron, chromium, and nickel in the effluents of a pharmaceutical company in Ogbomoso, Oyo State, South-West Nigeria. The study further shows that the soil samples were polluted (pollution index greater than one) with heavy metals present in the pharmaceutical effluent. This could impact negatively on the living organisms such as microorganisms in the soil and the vegetation planted on such soil or those that are cultivated with the effluents as source of irrigation. Consequently, this could have negative health implication on the humans who feed on such crops.

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